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CATCHWORD

Digital Sustainability

Understanding and Managing Tensions

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1 Motivation

The information systems (IS) community and beyond recognize the immense potential of digital technology in driving sustainability forward (e.g., Watson et al. 2010; Seidel et al. 2013; Sachs et al. 2019; van der Aalst et al. 2023). Prior IS research highlights the power of actor sensor networks (Watson et al. 2010), artificial intelligence and analytics (Ketter et al. 2020; Schoormann et al. 2023b), data practices (Krasikov and Legner 2023; Püchel et al. 2024), and affordances of information systems (Seidel et al. 2013) to become more sustainable. Technologies have improved the ability to act sustainably in numerous areas of our lives. Take, for instance, the capability of energy management systems to adjust consumption behaviors (Graf-Drasch et al. 2023), that of telemedicine to provide access to healthcare (Fürstenau et al. 2023), and the capacity of predictive security to create safe environments (Walter et al. 2017).

Digital sustainability is an emerging paradigm which investigates how data and digital applications contribute to sustainable development. While the first waves of sustainable IS research focused on reducing the environmental impact, we now recognize a shift towards more nuanced and holistic thinking about the environmental and social impacts of technologies. The broader focus, however, comes with a growing complexity. It requires both scholars and practitioners to manage tensions between conflicting goals, supposedly incompatible goals, and their positive and negative outcomes, whether intended or not. Tensions involve two or more interdependent opposites that coexist in a state of unified opposition and fuel ongoing conflict and change (Benson 1977; Ciriello and Mathiassen 2022). Those opposing views are well known in sustainability (Purvis et al. 2019), such as between achieving prosperity for all and contributing similarly to the environmental conversation, or achieving economic growth without harming the planet's resources. Failing to account for tensions would undermine the complex and multi-dimensional essence of sustainability (Hahn et al. 2015). We also observe tensions between positive and negative narratives (Chatterjee and Sarker 2024) in the context of digital technologies. Examples are: Technostress (Adam et al. 2017), the spread of misinformation (Dennis et al. 2021), environmental harm through energy-intensive applications (Sedlmeir et al. 2020), and algorithmic discriminations

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(Feuerriegel et al. 2020). In design science research, scholars even explicitly distinguish between design artifacts' direct and indirect effects to capture all outcomes (vom Brocke and Seidel 2012).

Although the initial intent behind the introduction of technologies may be well-meaning, decisions on the design and use must take into account their broader implications. This constitutes the idea of digital sustainability. Digital sustainability intends to identify potential tensions between competing goals and explore how to resolve them. It reflects that digital technologies need to be managed responsibly to mitigate unintended consequences for people, industries, and economies (Rossi et al. 2024). Such consequences are unforeseen side effects that can either be positive or negative (Rizun et al. 2021), which we refer to as the *bright* or *dark* side of digital sustainability. This catchword article therefore proposes *the digital sustainability cube (DSC) that sheds light on possible tensions within and between sustainability dimensions occurring from designing or using digital technology*.

We are responding to the call for more diversified perspectives in sustainable IS, which is accompanied by new challenges. For example, these could be conflicting requirements due to often wicked problems (Naidoo and Gabryk 2022), higher interconnectivity of sustainability goals (Haugjord and Aanestad 2023), and the tie between digital and sustainability transformation (Christmann et al. 2024). Since we cannot overcome those issues easily, we need to be able to understand their tensions. Formulating both the bright and the dark side allows us to anticipate unintended consequences in the early stages of digital technology's design and application. This paves the ground for managing digital sustainability by crafting responses for mitigation and weighing up possible rebound effects (Hertwich 2005).

This article aims to introduce and conceptualize digital sustainability by making three specific contributions: (1) to present the relevant research that constitutes today's broader understanding of sustainability, (2) to raise awareness for the consequences of designing and using digital technologies, and (3) to pave the way for BISE research on reflecting, balancing, and mitigating sustainability impacts.

2 Moving Towards Digital Sustainability

Research on digital sustainability considers that the discourse at the intersection of sustainability and IS (e.g., Loos et al. 2011; vom Brocke et al. 2013; Kranz et al. 2022; Schoormann and Kutzner 2020; Trier et al. 2023) has always recognized the wider understanding of sustainability, also referred to as the triple bottom line (Norman and MacDonald 2004). More than a decade ago, Seidel et al. (2013) reported on economic, environmental, and social sustainability in IT-enabled transformations, and before the UN's SDGs were published IS scholars already pointed to the role of IS in solving our grand challenges with significant societal, economic, and environmental impacts (Becker et al. 2015; Mertens and Barbian 2015). Building upon the existing nature of IS research, digital sustainability uses digital resources (e.g., data and technical infrastructure) and digital artifacts (e.g., software applications) to address different sustainability goals (e.g., Pan et al. 2022; Kotlarsky et al. 2023) (see definitions in Table 1).

The extant understanding highlights the extensive impact across sustainability dimensions while placing less emphasis on the potential conflicts that emerge from adopting such a broad perspective. In this catchword article, we complement this understanding by adding a nuanced perspective on tensions between and within sustainability dimensions in the design or use of technology. As technologies create both novel opportunities and undesirable or even harmful issues, the outcomes need to be managed before, during, and after their application in the real world. This allows us to anticipate a broader range of possible outcomes and develop coping mechanisms early on.

3 Raising Awareness of Digital Sustainability Outcomes

In this section, we present our DSC for conceptualizing digital sustainability (see Fig. 1). The cube distinguishes between activities for specifying a sustainability goal, designing and using digital technologies as a means to achieve that goal, and managing sustainability outcomes.

Sustainability goals broadly refer to the overall aim to contribute to an economic, environmental, or/and social objective, such as structured by the 17 SDGs, or the recognition of a sustainability-related problem that should be solved through digital technologies. Beyond the specific objectives within digital sustainability, the outcome dimensions will also be relevant for the general design and use of technologies that pursue non-sustainability goals but lead to various consequences.

Digital technologies can create value by reconfiguring combinations of digital data and algorithms (Yoo et al. 2010). The decoupling of the physical and digital devices and the software-based service can execute a sheer unlimited potential of functionalities, such as given by Large-Language Models used in Generative AI. To highlight the nuances of digital technologies, Baier et al. (2023) conceptualize – following Yoo et al.'s (2010) device,

Table 1 Selected definitions of digital sustainability

Reference	Definition: digital sustainability	Focus
Kotlarsky et al. (2023, p. 938)	"[..] the development and deployment of digital resources and artifacts toward improving the environment, society, and economic welfare."	Digital resources and artifacts, all sustainability dimensions
George et al. (2021, p. 1000); also in Pan et al. (2022)	"[..] organizational activities that seek to advance the sustainable development goals through creative deployment of technologies that create, use, transmit, or source electronic data."	Data and technologies, sustainable development goals
Owsiany and Brohman (2024, p. 2)	"[..] technology-driven sustainable impact across environmental, social, and economic dimensions – both positive and negative."	Technology, positive and negative impact, all sustainability dimensions
Haugjord and Aanestad (2023, p. 10)	"[..] the use of digital technology to positively affect several dimensions of sustainability."	Digital technology, multi-dimensional sustainability

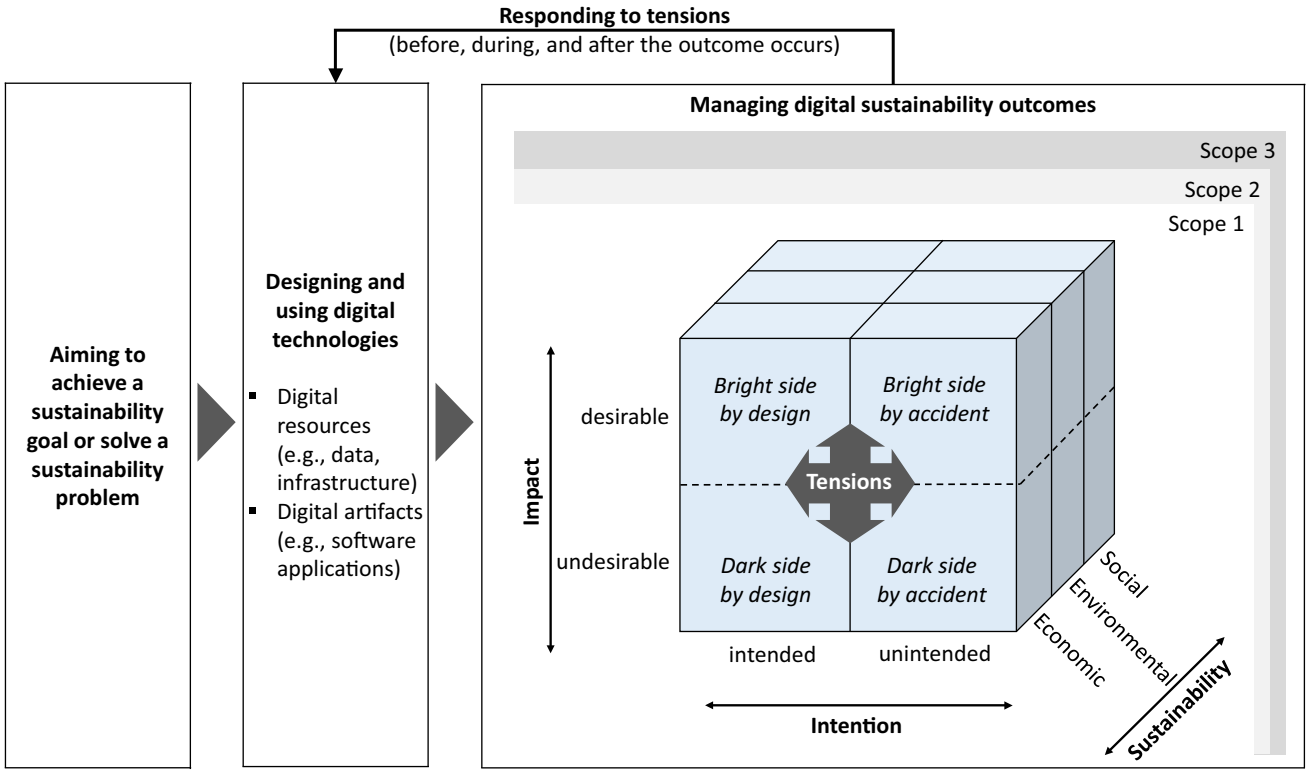

Fig. 1 Digital sustainability cube (DSC)

network, service, and content layers – two major classes: infrastructure to enable data sharing and provide a foundation for advanced activities; applications that directly engage with end-users and help fulfilling tasks. This is comparable to recent digital technology descriptions differentiating between digital resources like data and digital artifacts like applications and systems (Kotlarsky et al. 2023). The widespread use and access to digital resources and artifacts pave the way for flourishing technology and applications for sustainability.

Digital sustainability outcomes are positioned along with the dimensions of *intention*, *impact*, and *sustainability*. Parts of this have already been discussed in prior research, such as unintended consequences of technology (e.g., Parks et al. 2017). The dimensions describe the outcome as a snapshot in time. However, as these outcomes can occur at different points, we integrate a scope component to highlight whether it is achieved directly or indirectly: *Scope 1* refers to direct outcomes owned or controlled by the technology designer/user; *Scope 2* captures indirect outcomes from designing/using technology; *Scope 3* consists of all other indirect outcomes. Between and within these dimensions, **tensions** – i.e., tradeoffs, competing sustainability goals, and dependencies

– can arise. These tensions need to be managed responsibly to reflect on and mitigate (Ciriello et al. 2019) emerging consequences of digital technologies of both positive and negative nature.

Next, we first introduce the main DSC pieces to create awareness of the spectrum of IS research outcomes and then discuss examples of tensions between the outcomes.[1]

3.1 Bright Side by Design (Desirable Intended)

Digital sustainability accelerated the idea of addressing a broad range of sustainability goals, which is why we can see positive outcomes across various dimensions. Data as a digital resource can promote sustainability, such as by monitoring labor conditions along the worldwide supply chain to tackle social issues concerning child labor (Wang 2021) or tracking product information in detail to enable environmental-friendly reuse and circularity (Hoppe et al. 2024). Numerous examples show how digital artifacts intentionally solve important problems. Take, for instance, the BISE community that has designed artifacts in the form of behavior change systems for blood donations (Müller and Reuter-Oppermann 2024), game-based learning tools to teach cybersecurity (Rajendran and Sundarraj 2024), and smart green IS to craft sustainable urban environments (Graf-Drasch et al. 2023). A particular boost can be achieved through the application of artificial intelligence-based technologies, for example, transformer neural networks to assist sign language translations (Strobel et al. 2023).

3.2 Bright Side by Accident (Desirable Unintended)

Unintended consequences typically occur rather indirectly during or after the use of digital technologies. It is challenging to grasp them beforehand because they can have second-order (e.g., a system for collaboration also reduces emissions) or even third-order scope impact (e.g., long-term adaption of cultural and behavioral factors) (Owsiany and Brohman 2024). Desirable unintended impacts can be based on both positive and negative intentions. The collection and processing of organization-wide data for sustainability reports might not only lead to appropriate reporting and compliance but also to more reflected and possibly changed behavior of employees as they start to engage with this information in greater detail (Garcia-Torea et al. 2023). Vice versa, negative intentions to greenwash an organization's report could also lead to positive impacts on the employees. Concerning digital artifacts, for example, decision support systems to improve the economic performance of fleet logistics can lead to reduced carbon emissions in a district due to minimized traffic (Owsiany and Brohman 2024), and digital surveillance can lead to increased compliance with desirable working standards.

3.3 Dark Side by Design (Undesirable Intended)

A danger shared with almost any tool, digital technologies might be applied intentionally to cause a direct negative scope impact on individuals, communities, society, or nature. For instance, digital surveillance (Grisold et al. 2024) can be used to track and analyze personal information resulting in opportunities for malicious use, or cyberattacks (Plachkinova and Vo 2023) to harm critical infrastructure and people. and the malicious use of such information to harm people. Also, data can be manipulated or adjusted to meet certain criteria and improve an organization's image as known from greenwashing issues. Among the most dangerous uses of digital artifacts is the spread of disinformation, i.e., false or misleading information communicated on purpose. Well-known as fake news, this manipulated information is often distributed through social media platforms and has received public attention in situations such as the US elections (Dennis et al. 2021).

Although this might not be on purpose, we position this as "intended" because there is rather a direct relationship between using digital technology and a negative, unsustainable impact.

3.4 Dark Side by Accident (Undesirable Unintended)

In contrast to good intentions, numerous risks and downsides of digital technologies that have not been anticipated can occur during or after their use in the real world. Undesirable impacts, therefore, need to be reflected and managed early on. In terms of data, common threats include the energy-intensive storage and sharing of data (Sedlmeir et al. 2020), as well as data privacy risks, theft of digital identities, and unauthorized disclosure of private/business data (Sachs et al. 2019), for which reason sustainable handling of data becomes a major challenge. The use of digital artifacts without bad intentions leads, among other impacts, to the growing digital divide in which only limited people with suitable devices have access to important healthcare and public services (Weinhardt et al. 2024), risks of fueling discrimination through algorithms (Feuerriegel et al. 2020), mental health issues and stress (Adam et al. 2017), and loss of jobs through technology replacements (Sachs et al. 2019).

[1] Please note that it depends on the stakeholder's perspective if an outcome is desired or not. While an impact might be beneficial for one group, it could simultaneously be detrimental for another.

4 Managing Tensions Between Sustainability Outcomes

The comprehensive understanding of digital sustainability accounts for the multifaceted consequences that decisions on the design and use of digital technology for sustainability have. Digital sustainability embraces complexity, as such decisions often deal with wicked problems in which consequences are nested, connected, and even conflicting. Complexity in IS design has been studied intensively, like in design research where it is addressed by decomposition and concurrent validation (Tuuanen et al. 2024). Against this backdrop, we infer that the anticipation and management of potential tradeoffs related to digital sustainability becomes an essential task for future scholars. Next, we describe three examples.

4.1 Digital Product Passports: Managing Environmental Benefits with Economic Costs

A prominent example of a digital technology aimed toward sustainability is the Digital Product Passport, a data set combined with digital product identifiers and interfacing technology (Jensen et al. 2023). They are embedded in the Ecodesign for Sustainable Products Regulation (ESPR) and mandate organizations to equip physical goods (e.g., batteries or textiles) with a digital representation of the product and its life cycle data (Langley et al. 2023). Such passports require a sound set of data about products that need to be shared across supply chain actors or industrial data ecosystems (Möller et al. 2024). Digital product passports can produce the intended positive environmental outcomes of reducing Greenhouse Gas Emissions (GHG) through circularity, efficient material reuse, and ensuring compliance with supply chain regulations. Conversely, unintended negative effects can occur, such as replacing low-skilled jobs through automation or the demand for new IT infrastructure (Battery Pass Consortium 2024). Also, the data of such passports hold sensitive personal or business data, which could be shared with 3rd parties (Ducuing and Reich 2023), leading to data leakage and increased costs for data security.

Potential ways to manage these tensions are to enforce strict data governance policies capable of ensuring responsible data use (Machado et al. 2022), adopt sustainable data governance approaches to harness the strategic potential of data (Lefebvre and Legner 2024), or include technical and design provisions to minimize, for example, the issue of unwarranted data access (Heeß et al. 2024).

4.2 Digital Welfare Applications and Automated Decision-Making: Managing Economic Efficiency with Mental and Social Harm

An illustrative example from the broader class of undesirable consequences from AI and automation is the Australian 'Robodebt' case (Rinta-Kahila et al. 2024). Given that public administrations face increased demands to become more efficient, they apply digital technologies to automate and support their processes. In this case, the agency delegates human tasks for the distribution of social security payments to algorithmic decision-making systems.

Table 2 Illustrative tensions between sustainability dimensions

Tension	Intension	Impact (unintended)
Bright to dark side	Improved performance for personal services through data (economic)	Data privacy risks, unallowed data sharing, theft of digital identities (social)
	Algorithmic decision support for human health treatments (economic, social)	Possible discrimination through bias, digital divide (social)
	Waste reduction through monitoring environmental data (environmental)	Increased energy consumption, emissions (environmental)
Dark to bright side	Manipulated data-sourcing for sustainability reports (economic)	Positive behavior change (social)
	Digital surveillance to (illegally) monitor employees (social)	Following safety standards meticulously (social)
Bright to bright side	Advanced sustainability reporting (to increase company image) (economic)	Positive behavior change (social)
	Decision support systems for optimizing fleet logistics (economic)	Reduced carbon emission, traffic issues (environmental)
Dark to dark side	Management of an ecosystem with winner-takes-it-all principles (economic)	Loss of jobs, bankruptcy of small companies (social, economic)
	Dark web to sell illegal items and increase own success (economic)	Increased energy use, societal harm (environmental, social)

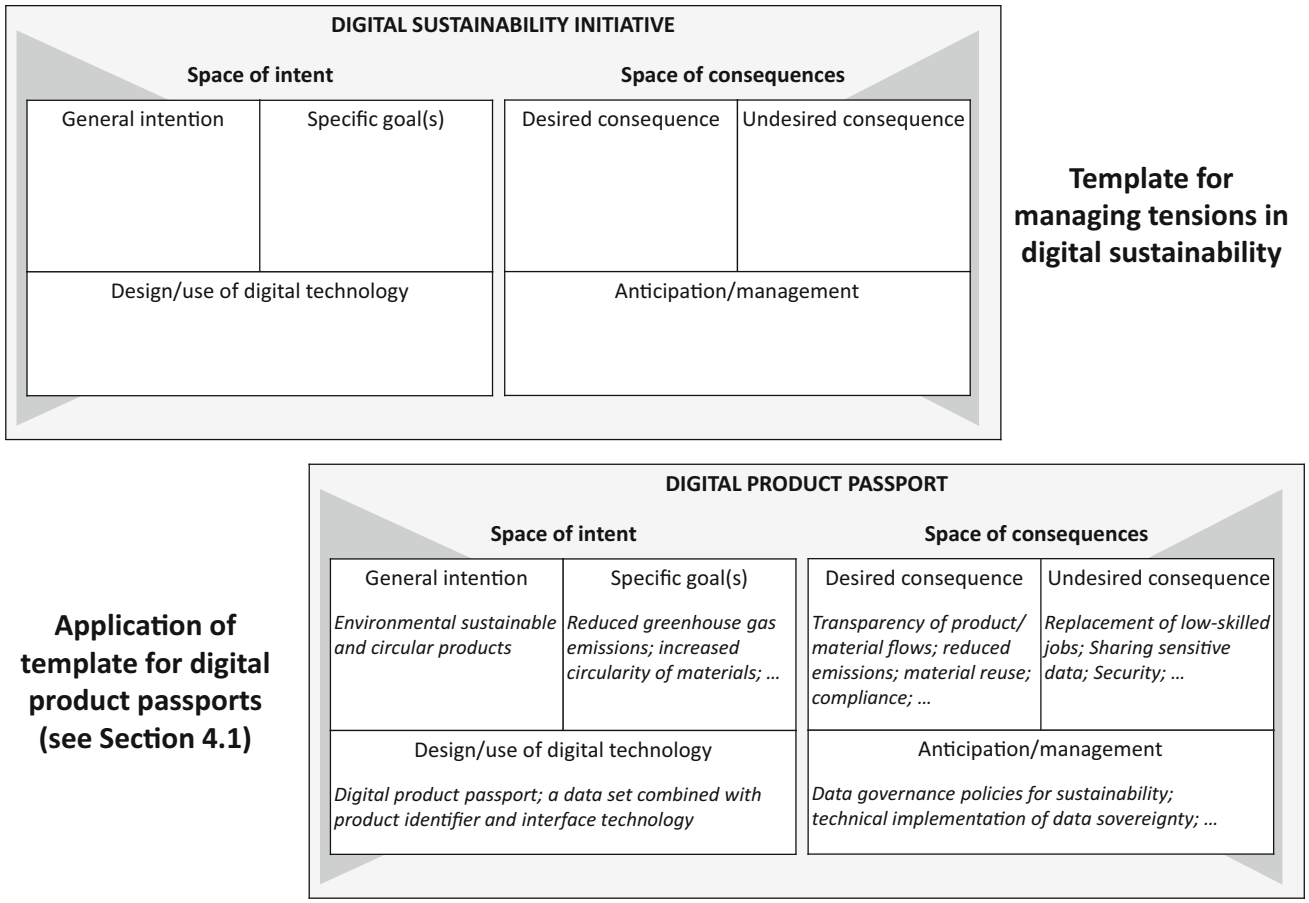
DIGITAL SUSTAINABILITY INITIATIVE
Space of intent
Space of consequences
General intention
Specific goal(s)
Desired consequence
Undesired consequence
Design/use of digital technology
Anticipation/management
Template for managing tensions in digital sustainability
Application of template for digital product passports (see Section 4.1)
DIGITAL PRODUCT PASSPORT
Space of intent
Space of consequences
General intention
Environmental sustainable and circular products
Specific goal(s)
Reduced greenhouse gas emissions; increased circularity of materials; …
Desired consequence
Transparency of product/ material flows; reduced emissions; material reuse; compliance; …
Undesired consequence
Replacement of low-skilled jobs; Sharing sensitive data; Security; …
Design/use of digital technology
Digital product passport; a data set combined with product identifier and interface technology
Anticipation/management
Data governance policies for sustainability; technical implementation of data sovereignty; …

Fig. 2 Example of anticipating, describing, and managing tensions

By automatically investigating discrepancies between benefits payments and earning reports, they intend to improve efficiency, achieve savings, and reduce 'welfare fraud'. However, flawed and biased calculations with automatically sent notices to repay 'debts' resulted in negative consequences for the broader society, including great distress and mental (e.g., depression and anxiety), social, and financial crisis (Rinta-Kahila et al. 2024).

Besides advanced technical validation, designers might draw on inclusive design research to respect all stakeholders affected by a digital artifact already during the building stage (Wass et al. 2023), users ensure responsible handling of algorithms (Trier et al. 2023), and developers reflect on possible risks (Schoormann et al. 2023a) to manage potential consequences.

4.3 Digital Ecosystems for Commerce: Managing Economic Development with Social and Environmental Harm

E-commerce villages established particularly in rural areas of China by tech champions, such as Taobao villages, transformed local economies into worldwide operating internet sellers. Those villages were mainly created with the intention of improving the economic development of rural residents to overcome poverty issues. On the bright side, the consequences of these digital-enabled initiatives resulted in the empowerment of marginalized communities, novel entrepreneurial opportunities, and open innovation (Leong et al. 2016; Peng et al. 2019). In contrast, undesirable impacts cover the out-migration of local communities, affected social relationships due to intensive competition, and environmental degradations through packaging and waste problems (Leong et al. 2016).

Responses to manage the consequences might include responsible ecosystem governance to anticipate and mitigate consequences or citizen science approaches to closely work together with local communities and understand their needs (Weinhardt et al. 2020). Gau et al. (2025), for instance, have presented the design of an open research system for collaborative problem exploration, which can be used to capture different stakeholder perspectives right from the beginning of a project.

Table 3 Research avenues for managing tensions of digital sustainability

Research avenue	Example research questions	Suitable BISE/IS research stream
Anticipation: Recognizing potential impact and tensions	How can AI be used to simulate 'what-else'-scenarios of possible consequences?	Scenario analysis; simulation; Prediction
	How can we enforce reflection on a broad set of consequences in greater detail?	Reflection-based systems; Digital nudging
	How to design and evaluate digital artifacts with minimal unintended impacts?	Inclusive design; responsible design; environmental design;
	What are possible extensions for existing design research methods?	
	How to use digital artifacts with minimal undesirable, unintended impacts?	Digital responsibility; responsible data science; explainable AI
Description: Identifying consequences and their tensions	What are the bright/dark consequences of designing and using digital technologies?	Tracking/monitoring systems; Data-sourcing practices
	What are conflicting consequences, i.e., possible tensions between them?	Paradoxical effects; dark pattern; bright pattern
	Are there patterns between conflicting/competing sustainability goals?	
	How can the consequences and tensions be described comprehensively?	Anatomy; Taxonomy
Management: Mitigating impact and responding to tensions	Which strategies help mitigate tensions during or after using digital technologies?	Dialectical inquiry; Regulatory design
	How do we couple different positive consequences to achieve a greater goal?	Design pattern
	How to handle non-manageable tensions from digital sustainability?	Reflection-based systems; Communication systems

4.4 Additional Examples of Possible Tensions

In a society in which the progression toward more sustainable behavior is paramount, the examples above highlight only a few of the tensions that need to be balanced. We expect these tensions to arise in areas using digital technologies and data. This implies a stark degree of rising complexity and a conscious mind about the pitfalls of good intentions. In Table 2, we elaborate on other typical tensions between and within sustainability goals, fully being aware that this is a snapshot of a large picture.

5 Implications for the BISE Community

Sustainability has been a core topic of the field of Business and Information Systems Engineering (BISE) for decades. There are promising reasons why the BISE community should engage and shape the future pathway of research at the intersection of digital technologies and sustainability, namely *digital sustainability*. By recognizing the multi-dimensional scope and considering the impact that results from the increasing complexity, we can support a shift towards consciously exploring possible tensions. This catchword article introduces the DSC to provide a nuanced and integrative view of existing research in the realm of digital technologies and sustainability.

The DSC helps to structure relevant dimensions and thus seeks to advance the understanding of how to use and design technology for digital sustainability. This immediately impacts scholars and practitioners, as it enables corporate executives and policymakers to effectively reflect on and characterize consequences from multiple angles when designing, using, or regulating novel technologies. Regarding regulation, the European AI Act presents a great example of where the dark side of AI is mitigated by assessing the risks. In doing so, it is also important to abstract from the specific technology and investigate its broader affordances (Seidel et al. 2024). The DSC helps raise awareness of a wider range of consequences, including unintended ones. For instance, using our illustrative case of implementing digital product passports (see Sect. 4.1), designers and users can make potential tensions more transparent (see example in Fig. 2). This raises awareness among stakeholders involved in digital sustainability projects and sparks the search for solutions to mitigate the risks.

Based on this catchword's elaborations, we see auspicious avenues for research (see Table 3). The avenues are

structured according to the three streams of anticipation, description, and management.

Anticipation takes place before digital technology is designed or used to allow for reflecting on potential consequences and their tensions. Researchers can, for instance, conduct scenario analyses to simulate and predict possible usage consequences or nudge the responsible use of digital technology to reduce dark impacts. From a design viewpoint, principles for inclusive and sustainable artifacts (e.g., vom Brocke and Seidel 2012; Wass et al. 2023) should be considered to mitigate issues before they arise.

Description focuses on identifying and being able to describe the consequences and tensions. Systems capable of tracking the use of digital technology, such as ones based on trace data, might be applied to indicate mishandling or undesired impact. These indications should be formulated (Hahn et al. 2015) using standardized templates to facilitate hypothesizing about causes and finding ways to manage them (see also Fig. 2). In addition to our cube, scholars also might find other dimensions important to describe digital sustainability, such as anticipation (Zwart 2015). If recognized and described, the *management* will develop mitigating strategies to respond to occurring tensions. Future research can utilize, for instance, dialectical inquiry to investigate responses from accepting certain tensions, via separating the opposite and specifying preferences, to finding holistic solutions (Ciriello and Mathiassen 2022). Also, it may be promising to explore how to achieve a greater sustainable goal is promising because it enables us to extract patterns and dependencies between consequences.

6 Conclusion

"*The road to hell is paved with good intentions.*" (song by In Fear and Faith) Although we might not take it as far as this quote suggests, we are witnessing emerging shifts towards a more diversified understanding of sustainability in the IS community, which comes with both opportunities and risks. The ongoing wave of digital sustainability provides new impulses for designing and using digital resources and artifacts to solve complex societal and environmental problems. At the same time, the increased complexity requires researchers to thoroughly mitigate possible tensions with undesirable outcomes. This catchword article, therefore, presents the DSC to raise awareness for the (un-)intended consequences of the design and use of digital technologies and paves the way for BISE research on the reflection and management of sustainability impacts.

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